

TITLE

METHOD AND SYSTEM FOR MASK FABRICATION PROCESS CONTROL

BACKGROUND

The present invention relates to mask fabrication and
5 particularly to a control system used in mask fabrication for
controlling feature critical dimensions (CD).

The critical dimension, or absolute size of a feature,
includes linewidth, spacing or contact dimensions. Errors in
mask critical dimensions have great impact during image transfer
10 to a wafer. Only a mask with correct critical dimensions can
correctly transfer an image onto a wafer. As optical lithography
pushes to smaller and smaller dimensions, patterned features
smaller than the wavelength of light must be routinely
manufactured. In this system mask errors make up an increasingly
15 large share of the sources of critical dimension (CD) errors.
Critical dimension control is affected by a variety of factors
including fabrication tools and equipment, recipes, and raw
materials.

Fig. 1 is a schematic view showing a conventional mask fabrication process. A conventional mask fabrication process includes writing, baking, developing, etching, after-etch inspection (AEI), re-etching, stripping of the photoresist, and
5 after-strip inspection (ASI) steps. Critical dimensions are largely determined by specific characteristics of the aforementioned steps. Accordingly, the process parameters of the writer and etcher are largely determined by device data of the processed mask and material data of the raw materials used
10 in the writing step. The inspection results obtained by the after-etch inspector and after-strip inspector are not utilized to fine-tune the processing conditions in the conventional mask fabrication systematically.

The greatest disadvantage of the conventional mask
15 fabrication process is that it is not effective in controlling CD variations. There is usually a substantial error rate in critical dimensions subsequent to the first etching step such that a re-etch step is needed. The re-etch step is costly and impacts the mask uniformity.

Client's ref.: TSMC2003-0940

File: 0503-A30088US/final/alicewu/

Hence, there is a need for a mask fabrication process that addresses the problems arising from the existing technology.

SUMMARY

It is therefore an object of the invention to provide a mask
5 fabrication system and method capable of statistical process control analysis, which analyzes causes of critical dimension variation during mask fabrication.

Another object of the present invention is to provide a mask fabrication system and method capable of controlling critical
10 dimension variation through adjusting recipe variables during mask fabrication.

Yet another object of the present invention is to provide a fabrication system and method capable of producing masks corresponding to defined critical dimensions without requiring
15 a re-etch process.

To achieve the above objects, the present invention provides a system and method capable of analyzing causes of critical dimension variation and controlling critical dimension variation through adjusting manufacturing models during mask

fabrication. By precisely controlling critical dimension, the mask fabrication system and method produces masks with preset critical dimensions without requiring a re-etch process.

According to one embodiment of the invention, a mask
5 fabrication system contains a processing tool, a metrology tool, and a controller. The processing tool processes a mask. The metrology tool inspects the mask to obtain an inspection result. The controller generates a manufacturing model of the processing tool and calibrates the manufacturing model according to device
10 data, material data, and the inspection result of the mask.

According to another embodiment of the invention, a mask fabrication method is provided. First, material and device data are provided. Second, a first manufacturing model is defined according to the material and the device data. Then a first
15 process run of a first mask is performed as defined by the first manufacturing model. At the same time, the first process data is collected during the first process run. Next, a backward modification data is determined according to the material, the device, and the first process data. Then, the first
20 manufacturing model is adjusted according to the backward

Client's ref.: TSMC2003-0940

File: 0503-A30088US/final/alicewu/

modification data to obtain a second manufacturing model. Next,
a second process run of a second mask is performed as defined
by the second manufacturing model.

The above-mentioned method may take the form of program
5 code embodied in a tangible media. When the program code is
loaded into and executed by a machine, the machine becomes an
apparatus for practicing the invention.

A detailed description is given in the following
embodiments with reference to the accompanying drawings.

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BRIEF DESCRIPTION OF THE DRAWINGS

The present invention can be more fully understood by
reading the subsequent detailed description and examples with
references made to the accompanying drawings, wherein:

Fig. 1 is a schematic view of a conventional mask
15 fabrication process;

Fig. 2 is a schematic view showing a mask fabrication system
according to one embodiment of the present invention;

Client's ref.: TSMC2003-0940

File: 0503-A30088US/final/alicewu/

Figs. 3A and 3B illustrate flowcharts of the mask fabrication method with run-to-run control of the system in Fig. 2;

Fig. 4 illustrates a flowchart of the mask fabrication method with real-time control of the system in Fig. 2; and

Fig. 5A and 5B are diagrams of a storage medium for storing a computer program providing a method for mask fabrication control according to one embodiment of the present invention.

DETAILED DESCRIPTION

The present invention will now be described with reference to Figs. 2 to 5, which in general relate to a mask fabrication system.

Fig. 2 is a schematic view showing a mask fabrication system according to an embodiment of the present invention. The mask fabrication system 20 contains at least one processing tool 21, a metrology tool 23, a controller 25, a database 24, and a manufacture executive system (MES) 26.

Processing tool 21 can be an exposure tool, a baker, a developer, an etcher, or a photoresist stripper. Metrology tool

23 executes an after-etch inspection or an after-strip inspection and obtains an after-etch inspection result or an after-strip inspection result respectively. Controller 25 is used for run-to-run control, including feed forward control and
5 feed backward control, of the processing tool 21. Controller 25 receives the after-etch or after-strip inspection result from metrology tool 23 and retrieves device and material data from database 24. Controller 25, connected with MES 26, generates a manufacturing model of the processing tool 21 and calibrates
10 the manufacturing model according to the device data, the material data, and the inspection result of the mask. Controller 25 also monitors operating conditions of the processing tool 21 and adjusts the manufacturing model of the processing tool 21 during the process.

15 According to this embodiment, the device and material data of the mask are stored in database 24. The device data of the mask includes device type data, mask layer data, mask grade data, optical correction type data, customer data, pattern loading data, and device loading data. The material data of the mask

relates to the raw materials consumed in the mask fabrication process, including data of photoresist post coating decay, batch relation and photoresist production date.

As illustrated in Fig. 2, controller 25, connected with MES
5 26, retrieves data for generating the manufacturing model of the processing tool 21. The manufacturing model includes a parameter set and recipe of the processing tool.

Fig. 3A is a flowchart of a backward control of the mask fabrication method of the system in Fig. 2. The mask fabrication
10 method as shown in Fig. 3 controls operation of processing tools in the mask fabrication system described above and shown in Fig. 2. The processing tool, controlled by the method shown in Fig. 3A, can be a writer, a baker, a developer, or an etcher.

First, material and device data are provided (step S31).
15 The material data mainly comprises information regarding photoresist and other raw material consumed during the fabrication process. The device data refers to a product for which the mask is designed. According to this embodiment, the material and device data are stored in database 24, which is
20 connected directly to the controller 25 or via a network.

Client's ref.: TSMC2003-0940

File: 0503-A30088US/final/alicewu/

Second, a first manufacturing model of the processing tool 21 is determined (step S32). The controller 25 retrieves the material and the device data from database 24 and determines the first manufacturing model of the processing tool 21 accordingly.

5 Next, a first process run of a first mask is performed according to the first manufacturing model (step S33). The first mask is processed sequentially by the exposure tool, baker, developer, and etcher. During the first process run, a first process data is collected (step S34). The first process data
10 is sent to the controller, and backward modification data is determined according to the material, the device, and the first process data (step S35). The backward modification data is determined using statistical methods. According to this embodiment, the material, the device, and the first process data
15 are assigned as nominal or continuing variables in accordance with the characteristics thereof. The static material data (such as photoresist type factor) and static device data (such as device type factor) are assigned as corresponding nominal variables respectively. The dynamic material, device and
20 process data are assigned as corresponding continuing variables

respectively. The nominal and the continuing variables are processed using ANOVA and regression analysis methods respectively. Next, the first manufacturing model is modified according to the backward modification data to obtain a second
5 manufacturing model (step S36). After the manufacturing model is modified, a second process run of a second mask is performed by the processing tool 23 according to the second manufacturing model (step S37).

As mentioned above, the first mask is processed in step S33.
10 If the critical dimensions of the first mask do not match a target value, the first mask will undergo a re-etch process to trim the critical dimensions until the target value is met. Referring to Fig. 3B, a flowchart illustrates a feed forward control of the mask fabrication method of the system shown in Fig. 2. First,
15 an inspection result of a preceding process run is received (step S331), wherein the inspection result is an after-strip inspection result. Next, a forward modification data is determined according to the first production data and the inspection result (step S333). Then a re-etch manufacturing
20 model is determined according to the forward modification data

(step S335). After the re-etch setting is determined, a re-etch process run of the first mask is performed as defined by the re-etch manufacturing model (step S337). The processing tool controlled by the method shown in Fig. 3B is an etcher or a photoresist stripper.

Fig. 4 illustrates a flowchart of the mask fabrication method with real-time control of the system in Fig. 2. First, a manufacturing model is defined (step S41). Then a process run of a mask is performed as defined by the manufacturing model (step S43). Then the tool is monitored to obtain operation conditions thereof (step S45). A fault detection analysis is performed during the process run to reduce bias in the manufacturing model (step S47). Then a fine-tuning signal is generated in response to a result of the fault detection analysis (step S48). Then the processing tool is adjusted according to the fine-tuning signal, and the process run is operated successively by the adjusted processing tool (step S49).

The run-to-run and real-time control methods discussed above can be implemented together or separately.

The method of the present invention, or certain aspects or portions thereof, may take the form of program code (i.e. instructions) embodied in a tangible media, such as floppy diskettes, CD-ROMS, hard drives, or any other machine-readable storage medium, wherein, when the program code is loaded into and executed by a machine, such as a computer, the machine becomes an apparatus for practicing the invention. The methods and apparatus of the present invention may also be embodied in the form of program code transmitted over some transmission medium, such as electrical wiring or cabling, through fiber optics, or via any other form of transmission, wherein, when the program code is received and loaded into and executed by a machine, such as a computer, the machine becomes an apparatus for practicing the invention. When implemented on a general-purpose processor, the program code combines with the processor to provide a unique apparatus that operates analogously to specific logic circuits.

Fig. 5A is a diagram of a storage medium for storing a computer program providing the run-to-run process control method according to the present invention. The computer program

Client's ref.: TSMC2003-0940

File: 0503-A30088US/final/alicewu/

product comprises a computer usable storage medium having
computer readable program code embodied in the medium, the
computer readable program code comprising computer readable
program code 51 for receiving material, device, first process
5 data of a mask, and an inspection result of a preceding process
run, a computer readable program code 52 for determining a first
manufacturing model according to the material and the device
data, and a computer readable program code 54 for determining
backward modification data according to the material, the
10 device, and the first process data, and a computer readable
program code 55 for modifying the first manufacturing model
according to the backward modification data to obtain a second
manufacturing model, a computer readable program code 57 for
issuing a process command to perform a second process run of a
15 second mask and a re-etch process run of the first mask as defined
by the re-etch manufacturing model, a computer readable program
code 58 for determining forward modification data according to
the first production data and the inspection result, a computer
readable program code 59 for determining a re-etch manufacturing
20 model according to the forward modification data.

Fig. 5B is a diagram of a storage medium for storing a computer program providing the real-time process control method according to the present invention. The computer program product comprises a computer usable storage medium having
5 computer readable program code embodied in the medium, the computer readable program code comprising computer readable program code 61 for receiving a manufacturing model, a computer readable program code 62 for performing a fault detection analysis to reduce bias in the manufacturing model, and a
10 computer readable program code 63 for generating a fine-tuning signal in response to a result of the fault detection analysis, and a computer readable program code 64 for adjusting the process run operation according to the fine-tuning signal.

While the invention has been described by way of example
15 and in terms of the preferred embodiments, it is to be understood that the invention is not limited to the disclosed embodiments. To the contrary, it is intended to cover various modifications and similar arrangements (as would be apparent to those skilled in the art). Therefore, the scope of the appended claims should

Client's ref.: TSMC2003-0940

File: 0503-A30088US/final/alicewu/

be accorded the broadest interpretation so as to encompass all
such modifications and similar arrangements.